Tech Brief

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Basic Water and Wastewater Formulas

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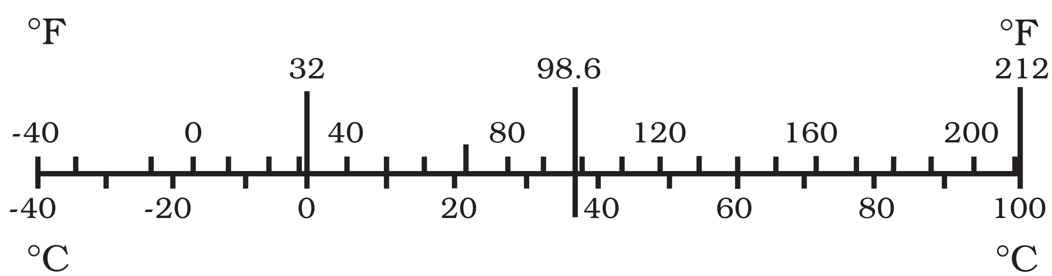
Summary

Operators obtaining or maintaining their certification must be able to calculate complex formulas and conversion factors. This *Tech Brief* provides basic examples of these formulas and conversion factors.

Metric Conversion Factors (Approximate)
Conversions from Metric Measures

Symbol	When You Know		Multiply By	To Find	Symbol
	mm	millimeters	0.04	inches	in
Length Area	cm	centimeters	0.4	inches	in
	m	meters	3.3	feet	ft
	m	meters	1.1	yards	yds
	km	kilometers	0.6	miles	mi
Mass (Weight)	cm^2	square centimeters	0.16	square inches	in^2
	m^2	square meters	1.2	square yards	yd^2
	km^2	square kilometers	0.4	square miles	mi^2
	ha	hectares ($10{,}000m^2$)	2.5	acres	acrs
	g	grams	0.035	ounces	oz
Volume Temp.	kg	kilograms	2.2	pounds	lbs
F= (9/5)C+32	t	tones (1,000kg)	1.1	short tons	
	ml	milliliters	0.03	fluid ounces	fl oz
	l	liters	2.1	pints	pt
	l	liters	1.06	quarts	qt
	l	liters	0.26	gallons	gal
	m^3	cubic meters	35.0	cubic feet	ft^3
	m^3	cubic meters	1.3	cubic yards	yd^3
	^0C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	^0F



Basic Water and Wastewater Formulas

Area, ft^2 — Rectangle, Width, *ft* x Length, *ft*
Circle, $\frac{(\text{Diameter}, ft)^2 \pi}{4}$

Backwash Rate, gpm/ft^2 — $\frac{\text{Flow}, gpm}{\text{Area}, ft^2}$

Filtration Rate, gpm/ft^2 — $\frac{\text{Flow}, gpm}{\text{Area}, ft^2}$

Chlorine Dose, *mg/L*
Cl_2 Demand, *mg/L*+Free Cl_2 Residual, *mg/L*

Circumference of a circle, *ft* — (π)(Diameter, *ft*)
or
2(π)(Radius, *ft*)

Detention time, *hrs* — $\frac{(\text{Volume, gal})(24\ hrs/day)}{\text{Flow}, gpd}$

Flow, *cfs* — (Velocity, *ft/sec*) (Area, ft^2)

Velocity, *ft/sec* — $\frac{\text{Flow}, cfs}{\text{Area}, ft^2}$

Velocity, *ft/sec* — $\frac{\text{Distance}, ft.}{\text{Time}, sec.}$

Water Horsepower, *HP* — $\frac{(\text{Flow}, gpm)(\text{Head}, ft)}{3960}$

Pounds, *lbs* (Flow, *MGD*)(Conc. *mg/L*)(8.34 *lbs/gal*)

Power, *watts* — (Voltage, *volts*)(Current, *amp*)

Power Factor — $\frac{\text{Actual Power, watts}}{\text{Apparent Power, V-A}}$

Removal, % — $\frac{\text{In - Out}}{\text{In}}$

Solution Strength, % — $\frac{\text{Weight of Chemical}}{\text{Weight of Solution}}$ x 100

Surface Overflow Rate, gpd/ft^2 — $\frac{\text{Flow, gpd}}{\text{Area}, ft^2}$

Temperature — °F (1.8 x °C) + 32
°C (°F-32) (5/9)

Velocity, *ft/sec* — $\frac{\text{Flow}, ft^3/sec}{\text{Area}, ft^2}$

Volume, ft^3

Rectangle; Width, *ft* x Length, *ft* x Height, *ft*

Cylinder; $\frac{\pi\ (\text{Diameter}, ft)^2\ (\text{Height, ft})}{4}$

Cone; $\frac{\pi\ (\text{Diameter, ft})^2 (\text{Height,ft})}{12}$

Sphere; $\frac{\pi\ (\text{Diameter}, ft)^3}{6}$

Reservoir Volume, gal. =

Volume, ac-ft x 43,560 ft^2/ac. x 7.48 gal/ft^3

Reservoir Surface Area, ac. =
$\frac{\text{Surface Area}, ft^2}{43{,}560\ ft^2/ac}$

Slope = $\frac{\text{Fall, ft}}{\text{Length, ft}}$

Grade = $\frac{\text{Rise, ft}}{\text{Run, ft}}$

Conversion Factors

1 ft^3 water = 7.48 gal	1 liter/sec = 15.85 gpm	1 kilowatt = 1.34 HP
1 yd^3 = 27ft^3	1 acre = 43,560 ft^2	1 HP = 550 ft-lbs/sec
1 gal water = 8.34 lbs	1 psi = 2.31 feet of water	1 HP = 0.746 kilowatts
1 ft^3 water = 62.4 lbs	1 mg/L = 1 ppm	1 meter = 3.28 feet
1 MGD* = 694 gpm	1% = 10,000 mg/L	1 mile = 5280 feet
1 MGD = 1.547 cfs	1 kilogram = 2.20 lbs	1 kilopascal = 0.145 psi
1 liter = 0.264 gal	1 centimeter = 0.394 inches	π (Pi) = 3.1416

*MGD = million gallons per day

Powers of Ten

Prefixes and symbols to form decimal multiples and/or submultiples.

Power of Ten	E Notation	Decimal Equivalent	Prefix	Phonic	Symbol
10^{12}	E+12	1,000,000,000,000	tera	ter'a	T
10^{9}	E+09	1,000,000,000	giga	ji'ga	G
10^{6}	E+06	1,000,000	mega	meg'a	M
10^{3}	E+03	1,000	kilo	kil'o	k
10^{2}	E+02	100	hecto	hek'to	h
10	E+01	10	deka	dek'a	da
10^{-1}	E-01	0.1	deci	des'I	d
10^{-2}	E-02	0.01	centi	sen'ti	c
10^{-3}	E-03	0.001	milli	mil'I	m
10^{-6}	E-06	0.000,001	micro	mi'kro	u
10^{-9}	E-09	0.000,000,001	nano	nan'o	n
10^{-12}	E-12	0.000,000,000,001	pico	pe'ko	p
10^{-15}	E-15	0.000,000,000,000,001	femto	fem'to	f
10^{-18}	E-18	0.000,000,000,000,000,001	atto	at'to	a

Sample Questions

1. An empty storage tank at standard atmospheric pressure (not under pressurized condition) is 8 feet in diameter and 32 feet high. How long will it take to fill 90 percent of the tank volume if a pump is discharging a constant 24 gallons per minute into the tank?

a. 7 hours and 31 minutes
b. 8 hours and 21 minutes
c. 8 hours and 23 minutes
d. 9 hours and 17 minutes

Solution: Don't look at the problem as a whole. Instead, break it into steps:

First, calculate the area of a circle 8 feet in diameter;

$\frac{(\text{Diameter, ft})^2}{4}\pi$, $\frac{8^2}{4}\pi$, $\frac{64}{4}\pi$, 16(3.1416)= 50.26 ft^2

Second, calculate the volume of a cylinder;

$\frac{(\text{Diameter, ft})^2}{4}\pi$ (Height, ft), *since the area is already calculated, just multiply by the height.*

50.26 ft2 x 32 ft high = 1,608.5 ft^3 (cubic feet)

Third, convert from ft^3 (cubic feet) to gallons;
1 ft^3 water = 7.48 gallons

1,608.5 ft^3 x $\frac{7.48\text{ gallons}}{\text{ft}^3}$ = 12,031.5 gallons, *this is total volume tank can hold*

Fourth, calculate what 90% of the total volume would be

12,031.5 gallons x $\frac{90\%}{100}$,
12,031.50 gallons x .90 = 10,828.39 gallons

Fifth, calculate time to pump at 24 gallons per minute

$\frac{10{,}828.39\text{ gallons}}{\frac{24\text{ gallons}}{\text{minute}}}$ = 451.18 minutes

Sixth, convert minutes to hours and minutes;
60 minutes = 1 hour

$\frac{451.18\text{ minutes}}{\frac{60\text{ minutes}}{\text{hour}}}$ = 7.52 hours

Now take the .52 hours and multiply by 60minutes/hour

7 hours and (0.52 x 60) = 31.2 minutes

7 hours and 31 minutes

The answer is a. 7 hours and 31 minutes

2. How many cubic feet of water will a rectangular tank that is 20-feet long by 15-feet wide and 10-feet high hold?

a. 2,000 cubic feet
b. 3,000 cubic feet
c. 850 cubic feet
d. 1,200 cubic feet

Solution:

Calculate the volume for a rectangular box (L x W x D or H) Length x Width x Depth or Height.

20 ft x 15 ft x 10 ft = 3,000 ft^3 (cubic feet)

The answer is b. 3,000 cubic feet

3. Calculate the chlorine demand using the following data:

Raw water flow is 0.75 MGD
Chlorinator feed rate is 4.0 mg/L
Chlorine residual (free) is 1.8 mg/L

a. 0.8 mg/L
b. 2.2 mg/L
c. 4.0 mg/L
d. 5.8 mg/L

Solution:

If solution strength is not given, then use 100%

Often more information is given than needed to solve specific problems. In this problem, the raw water flow rate (0.75 MGD) is not needed.

The equation to be used is the Chlorine Dose Equation

Chlorine Dose, mg/L =

(Cl_2 Demand, mg/L) + Free Cl_2 Residual, mg/L

Solve this Equation for the Chlorine Demand Cl_2, mg/L;

Cl_2 Demand, mg/L =

Chlorine Dose, mg/L – Free Cl_2 Residual, mg/L

Cl_2 Chlorine Demand, mg/L =
4.0 mg/L – 1.8 mg/L

Cl_2 Chlorine Demand, mg/L = 2.2 mg/L

The answer is b. 2.2 mg/L

4. Calculate the volume, in gallons, of a tank that is 75 feet long, 20 feet high, and 10 feet deep.

a. 15,000 gallons
b. 112,200 gallons
c. 150,000 gallons
d. 224,400 gallons

Solution:

First, calculate the volume for a rectangular box (L x W x D or H) Length x Width x Depth or

75 ft x 20 ft x 10 ft = 15,000 ft^3 (cubic feet)

Second, convert ft^3 (cubic feet) to gallons,
1 ft^3 (cubic feet) water = 7.48 gallons

$$15{,}000\ ft^3 \times \frac{7.48\ \text{gallons}}{ft^3} = 112{,}200\ \text{gallons}$$

this is the tank volume in gallons

The answer is b.112,200 gallons

5. How many pounds of a chemical applied at the rate of 3 mg/L are required to dose 200,000 gallons?

a. 1 lb
b. 3 lbs
c. 5 lbs
d. 16 lbs

Solution:

If a solution strength is not given, use 100%

The equation to be used is the pounds, lbs equation – (Flow, MGD)(Conc.mg/L)(8.34 lbs/gal)

Convert the flow or gallons to MGD;

$$\frac{200{,}000\ \text{gallons per day}}{1{,}000{,}000\ \text{million gallons}} = 0.2\ \text{MGD}$$

The concentration is the rate in this case = 3 mg/L

Now plug the givens (known) into the pounds equation

(0.2, MGD)(3 mg/L)(8.34 lbs/gal, day) = 5.004 lbs

The answer is c. 5 lbs

References:

Glover, Thomas J. 1999. *Pocket Reference*. Sequoia Publishing, Inc.: Littleton, CO.

National Environmental Services Center, 2007. *Basic Water & Wastewater Formulas Product #* DWPCOM84.

U.S. Navy. *Physics Formulas* notebook sheet.

Virginia Center for Very Small Water Works. 2003. *Sample Test Questions*. http://www.vaclassix.com/files/VSWS_samplequestions_answers.pdf

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